# GE Aviation
# CLEEN Systems Integration

Presenter: Jeff Bult

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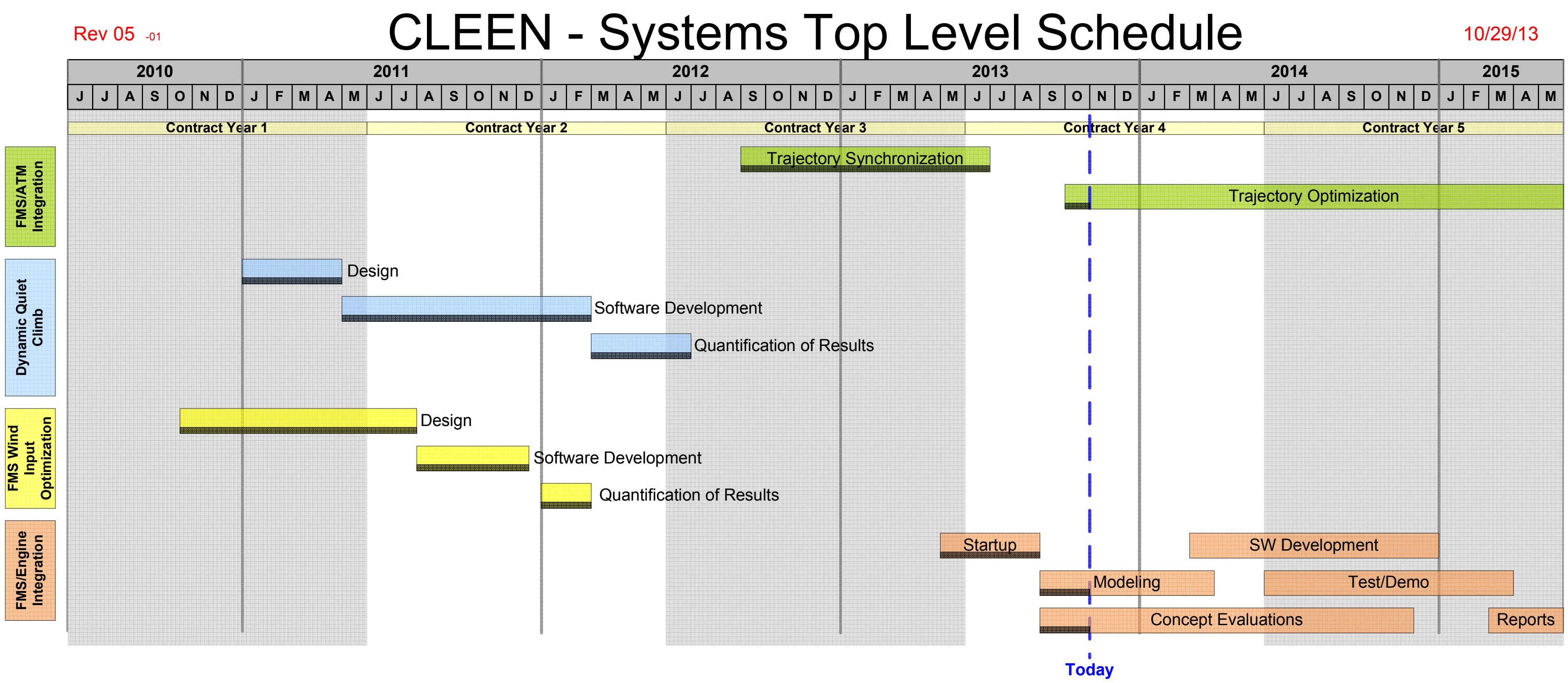
# Overview

## Energy, Emissions & Noise Reduction Objectives

| | Status |
|---|---|
| • FMS Efficiency improvements | |
| – Dynamic Quiet Climb | Complete |
| – FMS Wind Input Optimization | Complete |
| • FMS/ATM Integration | |
| – Trajectory Synchronization | Complete |
| – Trajectory Optimization Tasks | Ongoing |
| • FMS/Engine Integration | |
| – Adaptive Engine Control | Ongoing |
| – Integrated Vehicle Health Management | Ongoing |
| – Integrated Flight-Propulsion Control | Ongoing |

# Schedule for GE Aviation Systems Led Efforts

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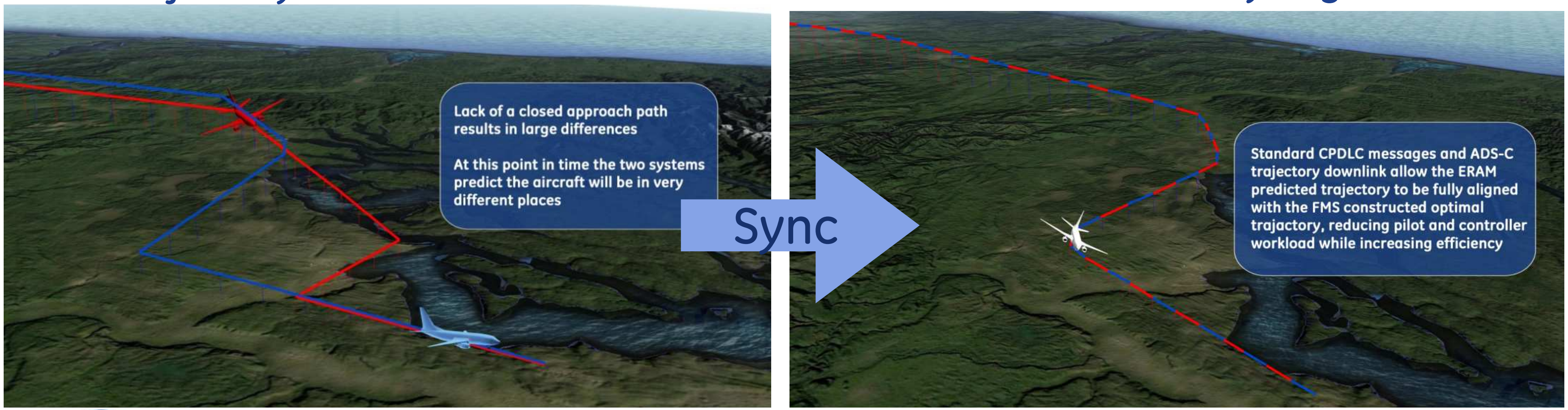
# Trajectory Synchronization

## Phase 1A

- **Core simulation** environment with integration and communication between aircraft and ERAM
- Incorporate **fast-time trajectory predictor** for primary aircraft
- **Single aircraft** position tracking throughout flight
- CPDLC / ADS-C EPP Implementation (Trajectory Downlink continuation)

## Phase 1B

- **Expanded** CPDLC / ADS-C **messages**
- Incorporate **simulated FMS (sFMS)** for primary aircraft
- Incorporate **multiple aircraft** capability using FPPD
- Expanded interface to ERAM
- Real-world environmental benefits
- **Demonstrate** at Embry Riddle Aeronautical University Flight Test Bed

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In collaboration with Lockheed Martin and Embry-Riddle Aeronautical University

# Trajectory Synchronization Benefits

- Greatly improves aircraft predictability
- Allows accurate conflict detection far in advance of the conflicts occurring
- Early mitigations to these conflicts in cruise are less drastic and much more efficient

## Benefit Analysis Scenarios

- **DEN→SEA:** Original flight vectored off plan for 44 seconds of delay, early conflict resolution measure added 44 seconds of delay via speed reduction
- **LAX→SEA:** Original flight put in hold pattern for 7 minutes 42 seconds of delay, early conflict resolution measure added 7 minutes 42 seconds of delay via speed reduction
- **MCI→SEA:** Original flight vectored at non-optimal altitudes and airspeeds for 18 minutes 51 seconds of delay, early conflict resolution measure added 18 minutes 51 seconds of delay via speed reduction (11:38) and path stretch (7:13)

## Benefit Analysis Results

| Flight Example (origin-->destination) | DEN-->SEA | LAX-->SEA | MCI-->SEA |
|---|---|---|---|
| ATC Time Delay to be Absorbed (min:sec) | 0:44 | 7:42 | 18:51 |
| Fuel Penalty due to ATC Vectoring for Delay (lbs) | 74 | 784 | 1,553 |
| Fuel Savings Due to Early Conflict Resolution Measures (lbs) | 112 | 869 | 1,049 |

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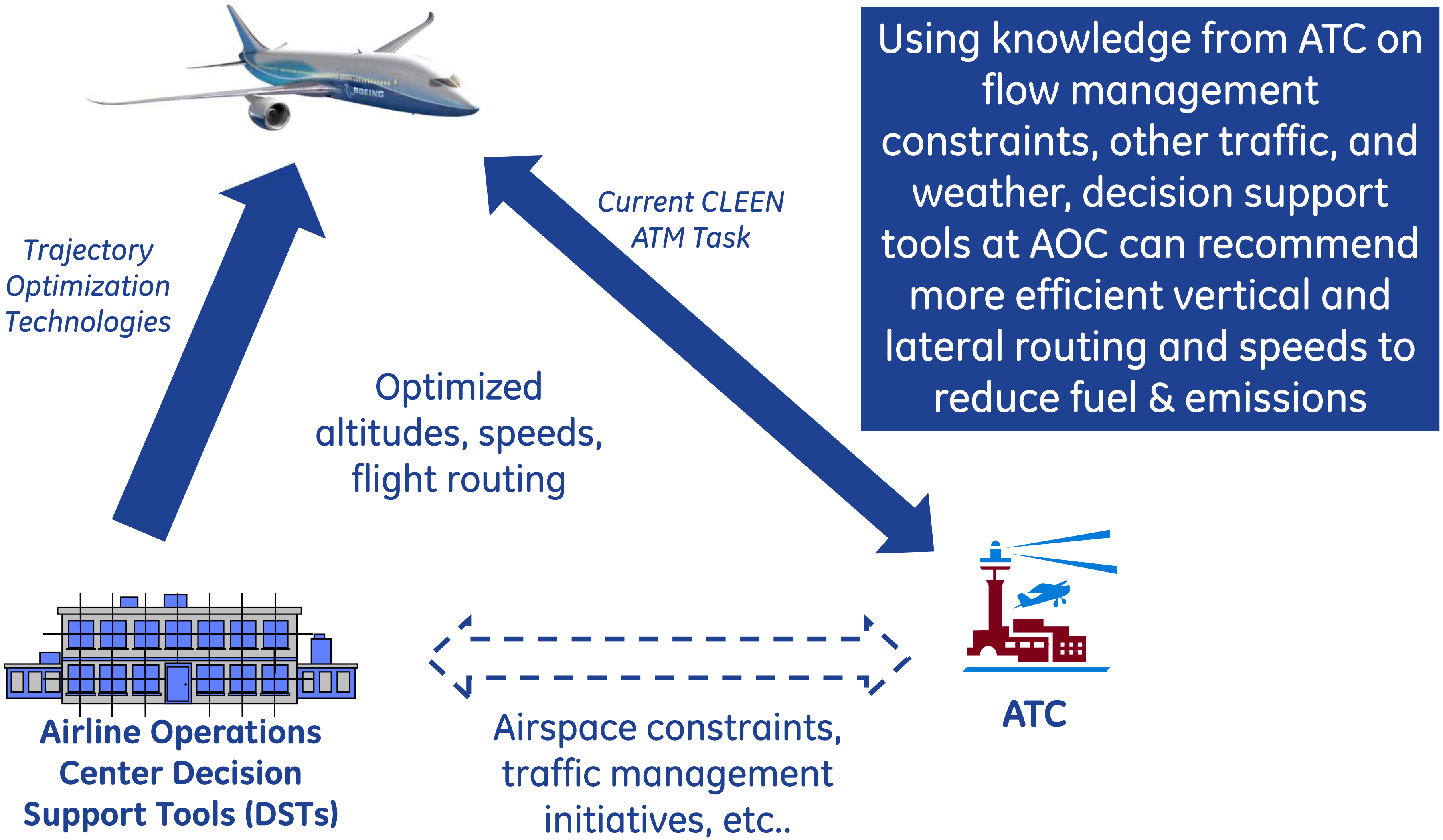
# Trajectory Optimization

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# GE Aviation

## FAA CLEEN
## Fuel-Burn Reduction
## (FMS-Engine Integration)

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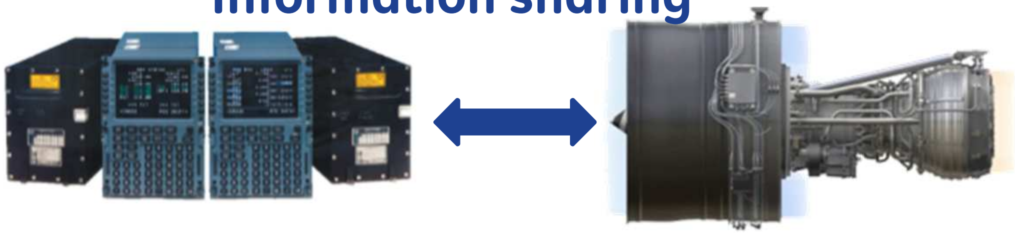
## FMS-Engine Integration Technologies – 3 Primary Focus Areas:

- Integrated Flight-Propulsion Control - Synergistic optimization of engine and aircraft
- Adaptive Engine Control - FMS for computation and communication with aircraft and ground systems
- Integrated Vehicle Health Management (IVHM) - Uses knowledge of engine health

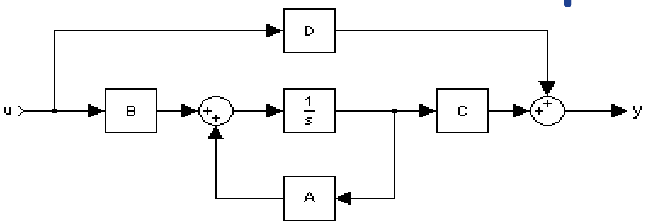
## State-awareness is key aspect of FAA CLEEN technology development & maturation

**Information sharing**



**Engine & Avionics**

**New control concepts and methods**




**Unified Model**

- Guidance & Navigation
- Flight Controls
- Engine Controls

**Simulation Controls**

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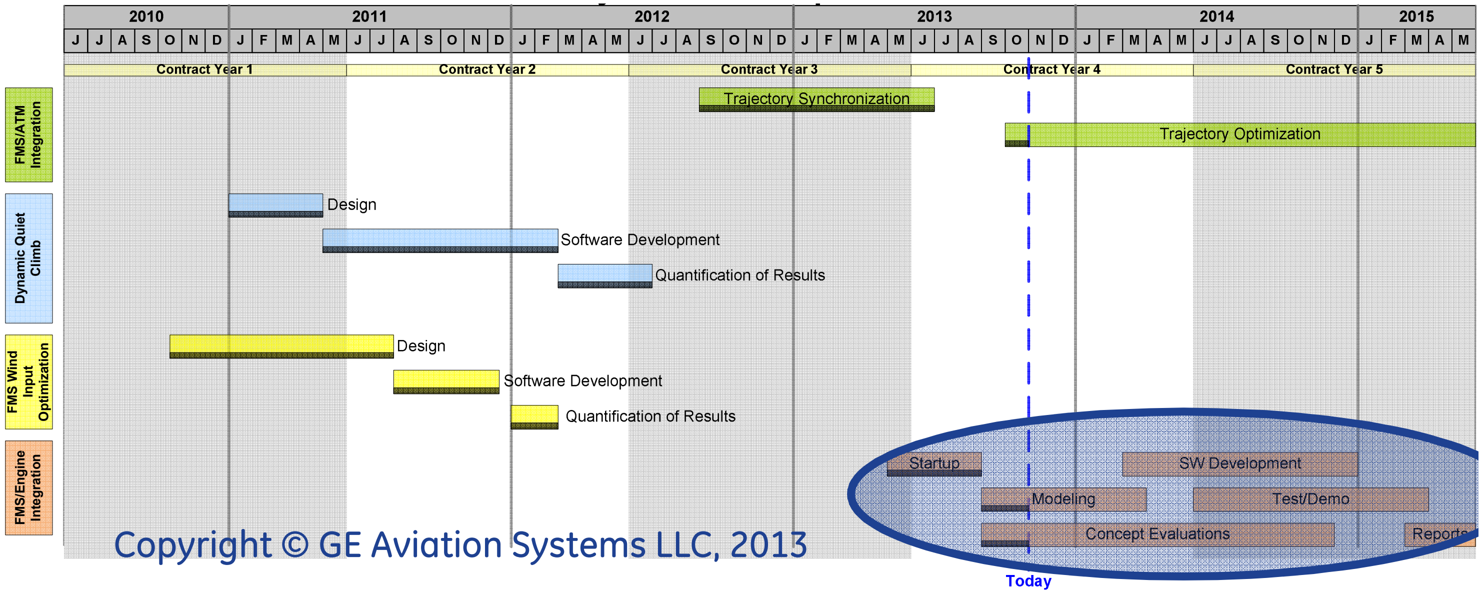
# Thirteen FMS-Engine technologies being evaluated

- Eight led by GE Aviation Engines
- Five led by GE Aviation Systems

# Execution Plan

- Modeling - Create integrated models of aircraft, FMS, and engine (TRL 3)
- Concept Evaluations - Analyze each idea to assess feasibility (TRL 3)
- Software Development - Modify software (TRL 4-5)
- Test/Demo - Perform hardware-in-the-loop laboratory tests and demonstrate benefits (TRL 6)



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# GE Aviation

## FAA CLEEN
## Fuel-Burn Reduction Using FMS-Engine Integration

Presenter: Shreeder Adibhatla

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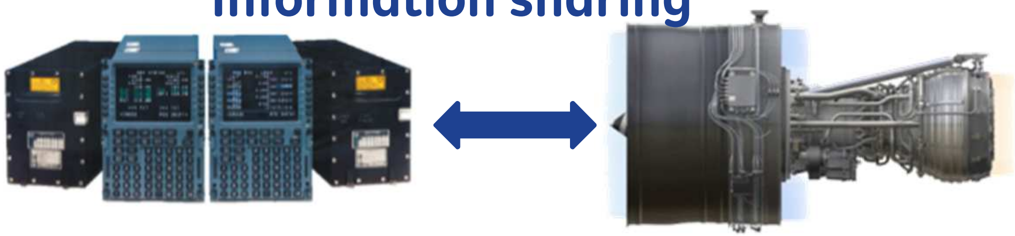
# FMS-Engine Integration Technologies – 3 Primary Focus Areas:

- Integrated Flight-Propulsion Control (IFPC) - Synergistic optimization of engine and aircraft
- Adaptive Engine Control – Uses knowledge of aircraft state and engine health to optimize performance
- Integrated Vehicle Health Management (IVHM) - Uses knowledge of engine health to optimize aircraft performance

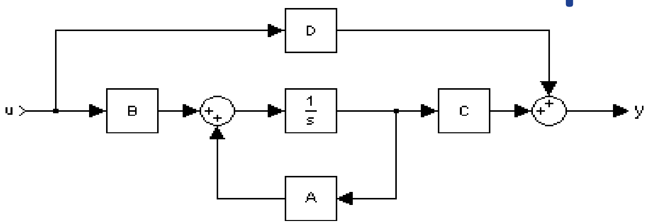
## State-awareness is key aspect of FAA CLEEN technology development & maturation

**Information sharing**



**Engine & Avionics**

**New control concepts and methods**




**Unified Model**

- Guidance & Navigation
- Flight Controls
- Engine Controls

**Simulation Controls**

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# Progress

Engine modeling effort completed, on-engine testing is continuing.

Integrated aircraft-engine-FMS model will be completed this year.

Control logic design tracking plan, first engineering release of FADEC with some of the concepts implemented will be next month.

Logic provided to airframers for desktop and iron bird testing, approved by airframers for implementation in product.

PFR and PDR for controls hardware completed.

Started hardware acquisition for concepts that require engine hardware modification for engine demo. of fuel burn reduction concepts.

Three of the technologies considered mature enough that they have bought their way onto specific  engine programs.

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